

Finite Element Modeling on Scalable Parallel Computers

Tom Cwik, Cinzia Zuffada and Vahraz Jamnejad

*Jet Propulsion Laboratory
California Institute of Technology
Pasadena CA 91109*

Dan Katz

*Cray Research Inc.
222 N. Sepulveda Blvd., Ste. 1406
El Segundo, CA 90245*

A coupled finite element-integral equation technique has been developed for modeling fields scattered from inhomogeneous, three-dimensional objects of arbitrary shape. The method incorporates a finite element model of fields in and near the scatterer with an integral equation that models fields on an arbitrary surface of revolution very near and circumscribing the scatterer. The integral equation is used to efficiently truncate the computational mesh without approximation. This method has also been extended to include various antenna radiators by modeling source fields such as those of a waveguide or coaxial feed and probe.

Finite element simulations become useful when stages of the computation- computer aided modeling, mesh generation, numerical solution of the discretized system, and field display-can be accomplished in a realistic amount of time for engineering design. Computer aided modeling of the volumetric regions of the scatterer or antenna, and the accurate generation of a finite element mesh that models the fields in these volumetric regions is typically accomplished using commercial packages. This stage must be closely linked to the specific algorithm used in the numerical solution of the fields. For example, in this work, Whitney edge elements are used to model fields in the region in and about the scatterer or antenna out to the minimal surface of revolution circumscribing the object. The stage of volumetric modeling and mesh generation can be time consuming for realistic structures, and presents one hurdle to efficient finite element simulations.

A second hurdle involves the efficient solution of the fields modeled by the finite element mesh. This stage involves both the storage of the sparse system of equations modeling the system, and an efficient solution of the system. The system can grow large when modeling electrically large structures, and considerable attention must be given to storage and solution algorithms. An iterative solver can be used to efficiently solve this system without excessive memory usage, and in a minimal amount of time if the convergence rate is controlled. Factorization algorithms can also be attempted, but they typically do not allow the solution of the large systems needed for realistic modeling in engineering design due to excessive memory usage.

Because of the large memories and speed of computation, scalable parallel computers can be used to address the issues outlined above. This talk will outline the issues in implementation, and the results of developing the coupled finite element-integral equation modeling software on a scalable parallel processor. The steps needed to interface the numerical solution code to the computer aided modeling and mesh generation will be outlined, as well as the implementation of a solver of the partitioned system of equations resulting from coupling the two formulations. This step involved the development of a parallel iterative solver for a large sparse system of equations. Results will be presented for realistic scatterers modeled by several-hundred thousand finite elements as well as different antenna radiators.